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# Vegetative Barriers affect Surface Water Quality leaving Edge-of-Field Drainage Pipes in the Mississippi Delta

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## ABSTRACT

Modified edge-of-field surface drainage pipes [slotted-board riser (SBR) pipes and slotted-inlet (SI) pipes] in the Beasley Lake watershed within the long-term, multi-agency Mississippi Delta MSEA (Management Systems Evaluation Area) project are being compared for their effectiveness in improving edge-of-field water quality. The SBR pipes have boards installed to impound water during the winter. Pipes [46-56 cm diameter (18-22")] are instrumented to facilitate automated collection of field runoff on a flow proportional basis. Instrumentation is relatively simple and compact, and involves an area-velocity flow logger and a small automated composite runoff sampler. The configuration is significantly less costly and less labor intensive than the traditional instrumentation involving a flume, larger instrument shelter (typically 1.2 m x 1.8 m or larger), flow-measuring device (typically a stage recorder), and full-size sampler. Runoff is being analyzed for pesticides, nutrients, and sediment concentrations. Discharge from pipes with and without upslope stiff grass hedges [switch grass (*Panicum virgatum*, Alamo variety)] are being compared from fields planted with no-tillage to Roundup-Ready® *Bt* cotton (*Gossypium hirsutum* L.). As this research is only recently underway, the purpose of the paper is to describe in detail the instrumentation, site setup, and treatments, as well as to present some early findings. The results of this research are expected to help the development of new tools, which may offer alternatives for runoff remediation and improve TMDL development accuracy.

**KEYWORDS.** water quality, BMPs, field drainage, TMDLs, watersheds, pesticides, nutrients, sediment, runoff

## INTRODUCTION

A hot, humid climate and long growing season make the Mississippi Delta well suited to intensive crop production, primarily cotton (*Gossypium hirsutum* L.), soybeans [*Glycine max* (L.) Merr.], rice (*Oryza sativa*), and corn [*Zea mays* (L.)]. However, these same conditions enhance weed growth and insect infestations, resulting in the need for intense agrichemical pest control measures. Because of the level topography and high annual rainfall, numerous streams, wetlands, and lakes are present. Many of the lakes are known as "oxbow lakes" because of their shape. Oxbow lakes are remnants of meandering floodplain rivers, which have been cut off and physically isolated from their respective main river channels, and usually capture only small relic drainages. Isolation has resulted in physical and chemical changes in the lakes' floral/faunal assemblages compared to the main channels. Over time, allochthonous (introduced from elsewhere) organic materials have been processed and energetically depleted, resulting in the lakes having become less heterotrophic and more autotrophic. If suspended sediment

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concentrations are low enough to provide suitable light penetration, isolated oxbow lakes provide conditions conducive to photosynthesis, primarily via phytoplankton, and may support sustainable fisheries production (personal communication S. S. Knight, USDA-ARS-NSL, 1996). However, decades of traditional agricultural practices including clean tillage and no winter cover on land surrounding these oxbow lakes have resulted in continuous high lake turbidity due to fine sediment transport in runoff. Thus, light penetration has been reduced, photosynthesis inhibited, and productivity lost. In addition, runoff has often transported agrichemicals into the lakes causing further reductions in water quality. Consequently, many Delta oxbow lakes, long known for their fish productivity and recreational value, have become unattractive.

The Mississippi Delta Management Systems Evaluation Area project (MDMSEA), part of a national research program entitled ***Agricultural Systems for Environmental Quality (ASEQ)***, being conducted by a consortium of Federal, State, and local agencies. Primary research agencies are the USDA Agricultural Research Service [ARS (Oxford and Stoneville, MS and Baton Rouge, LA locations)], the U. S. Geological Survey [USGS (Jackson, MS district office)], and the Mississippi Water Resources Research Institute [MWRRI (Mississippi State Univ.)].

Major objectives of the MDMSEA project have been: 1) develop alternative and innovative farming systems for improved water quality/ecology in the Mississippi Delta, 2) increase the knowledge to design and evaluate economical environmentally-sound best management practices (BMPs) as components of farming systems, 3) assess the effects of these agricultural activities on surface and shallow ground water quality, and 4) increase awareness and adoption by farmers/landowners of alternative farming systems to reduce adverse agricultural impacts on water resources and ecological processes.

Potential benefits from conducting this research include: 1) an increased knowledge of how the various physical, chemical, and biological properties of soils affect water and agrichemical movement, 2) the development of improved agrichemical transport models that allow for management, edaphic (inherent in the soil), and environmental variables, 3) new knowledge of agrichemical filter/processing system design and effectiveness, 4) improvements in crop residue and agrichemical management, 5) a reduction in agrichemical application with a concomitant reduction in sediment as well as surface and subsurface agrichemical transport, and 6) ecologically healthy lakes and streams with sustainable fisheries.

Modified field drainage pipes [slotted-board riser (SBR) pipes and slotted-inlet (SI) pipes] are variants within the Natural Resources Conservation Service (NRCS) practice “Grade Stabilization Structure” (Code 410) and are designed to control head cut erosion where concentrated runoff leaves cropped fields. These pipe structures, combined with vegetated buffers, are the edge-of-field water quality practices being evaluated within the MDMSEA. The SBR pipes have boards installed on the upslope side during the winter (shortly after crop harvest) to impound water. When the boards are removed (March through November), the SBR and SI pipes behave similarly and do not provide an impoundment for runoff events that do not create full-pipe flow. We hypothesized that placing a vegetative barrier (VB) (NRCS Code 601) upstream of the pipe inlets might increase sediment trapping for these smaller storm events, thus improving water quality. We further felt that to make this practice more acceptable and practical, we might need to install local subsurface drains close to the VB to avoid the development of wet areas where surface drainage was retarded. The impoundment serves as waterfowl habitat as well as a sediment settling basin for reducing sediment transport. The SI pipes have a larger cross section than a normal round pipe (e.g. culvert) to resist clogging with debris and thus to facilitate more rapid field drainage during rain storms.

The purpose of this paper is to present information on the details of field instrumentation, site setup, and treatments, as well as some early findings.

## PROJECT DESCRIPTION

The overall MDMSEA project design involves a hierarchy of BMPs in three research watersheds located in Sunflower and Leflore counties in west-central Mississippi (Figure 1). The watersheds are “closed systems” each with drainage into an oxbow lake. Thighman Lake watershed has served as a control with no project implemented BMPs initially. Beasley Lake watershed has received structural BMP treatment consisting of SBR and SI pipes, as well as

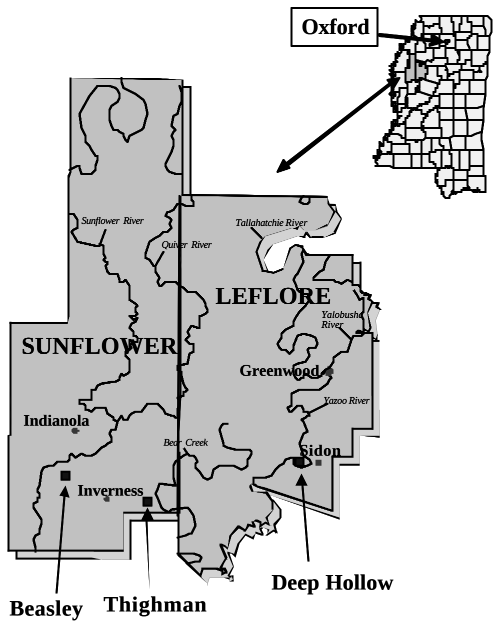


Figure 1. Watershed locations.

selected fields. Advantage is being taken of the existing large riparian zones around the lake.
Deep Hollow Lake watershed (smallest of the watersheds) has received an intense BMP effort (cultural and structural) consisting of winter wheat cover crop, all conservation-till cotton and soybeans, weed control using pioneering weed sensor technology, grass filter strips and stiff grass hedges, and SBR and SI pipes. As previously mentioned, success of the project can be demonstrated by reduced sediment and agrichemical transport in runoff, improved oxbow lake water quality/ecology, sustained profitable crop yields, and enhanced, sustainable fisheries in the oxbow lakes.

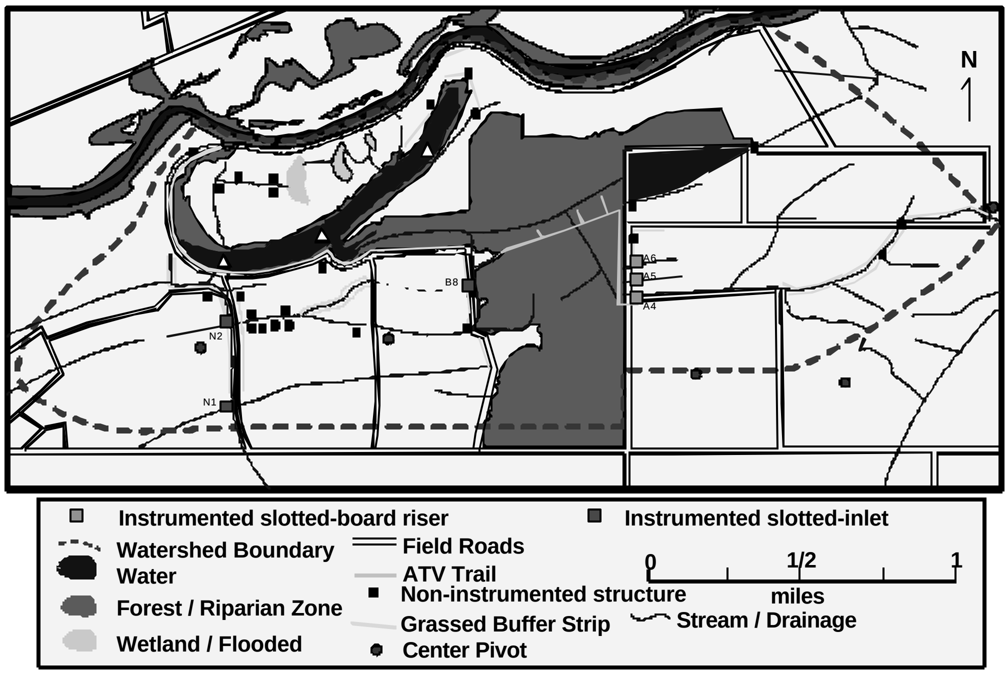


Figure 2. Locations of instrumented SBR pipes and SI pipes.

## MATERIALS AND METHODS

Site Setup

We established an experiment involving 6 grade control pipes within the Beasley Lake watershed. Three pipes were SBR pipes and three were SI pipes. We left two pipes (one SBR and one SI) as is, and planted a VB upslope of the other four pipes. Subsurface tile drains were installed under two (one SBR and one SI) of the pipes with the VB. Figure 2 shows the site locations for the SBR and SI pipes. SBR pipe sites A4, A5, and A6 drain about 4.2, 15.5, and 3.9 hectares (10.3, 31, and 9.6 A), respectively. Sites A5 and A6 each had a VB of switch grass (*Panicum virgatum*, Alamo variety) in a semi-circle in front on the upslope side during the summer of 2001. The purpose of the hedge is to slow and filter/process runoff approaching the SBR pipe. These fields were planted with no-tillage to Roundup-Ready® *Bt* cotton (*Gossypium hirsutum* L.). In 2001, site A6 also had 200 feet of drain tile [standard 10 cm (4”) perforated flexible drain line with nylon sock] upslope and through the stiff grass hedge to help (as previously mentioned) minimize ponding of water which often occurs on the upslope side of stiff grass hedges. The SI pipe sites are designated N1, N2, and B8 and drain about 10.1, 8.1, 5.3 hectares (25, 20, and 13A), respectively. Both sites N1 and B8 have a VB, with site N1 also having 300 feet of drain tile. All switch grass VBs were established by transplanting clumps of grass to form a solid barrier one or two rows wide during the spring or summer of 2001.

A small instrument shelter [91cm wide x 76 cm high x 48 cm deep (36”x30”x19”)] is adjacent to each pipe site and contains an Isco GLS automatic composite water sampler, an Isco 4150 area velocity flow logger with low profile area velocity sensor, and a 12 V deep cycle marine battery

(Figure 3). A 20 W solar panel on the roof of each shelter keeps the battery charged. The 4150 sensor mounts in the


Figure 3. SBR and SI pipes site with instrumentation.

bottom of the pipe with a stainless steel compression ring and uses Doppler technology to directly measure average flow velocity through the pipe and an integrated pressure transducer to measure flow depth in the pipe. By inputting the pipe diameter into the flow logger (via serial connector to a laptop computer), the flow logger calculates flow through the pipe and triggers the GLS sampler on a flow proportional basis. The GLS sampler contains a 9.5 L glass jar for collecting a single composite sample during a runoff event. Based on long term rainfall records for the area, the flow logger triggers the sampler to take a 75 mL sample for each 0.04 cm (0.015") of runoff. The sampler is programmed (via its keypad) to take up to 100 samples during a runoff event. Within 24h of a rainfall event, runoff samples are collected, placed on ice, immediately transported to the National Sedimentation Laboratory (NSL), and stored at 4°C (usually <24 h) for pesticide analyses via gas chromatography (GC). The flow loggers are also interrogated (data downloaded) at the same time as the samples are collected. The shelter at site N1 contains a cellular telephone which notifies NSL scientists when runoff is being collected at that site.

Pesticide analysis

Runoff samples are analyzed for pesticides (Bennett et al., 2000; Smith, 2001; and Smith et al., 2001) with two Hewlett Packard model 6890™ gas chromatographs each equipped with dual HP 7683 ALS autoinjectors, dual split-splitless inlets, dual capillary columns, a HP Kayak XA chemstation, and a HP LaserJet 4000 printer. One HP 6890 was fitted with two HP µECDs and the other 6890 with one HP µECD, one HP nitrogen phosphorus detector, and a HP 5973 mass selective detector (MSD). All pesticide analyses of samples (surface and ground water, sediment, soil, and plant material) collected in the MDMSEA and other NSL projects [e.g.

Demonstration Erosion Control (DEC)] are currently being conducted with this state-of-the-science technology.

Pesticides currently targeted for analysis are listed in Table 1. The main analytical column is a HP 5MS capillary column (30m x 0.25mm i. d. x 0.25µm film thickness). Column oven temperatures are as follows: initial at 75°C for 1min, ramp at 25°C/min to 185°C, hold at 185°C

Table 1. Currently targeted pesticides.

| | |
|---|---|
| **Trifluralin** | **Chlorfenapyr** |
| **Atrazine** | **p,p'-DDD** |
| **Methyl parathion** | **p,p'-DDT** |
| **Alachlor** | **Bifenthrin** |
| **Metolachlor** | **l-Cyhalothrin** |
| **Chlorpyrifos** | **Cyfluthrin** |
| **Cyanazine** | **Zeta-cypermethrin** |
| **Pendimethalin** | **Esfenvalerate** |
| **Dieldrin** | **Deltamethrin** |
| **p,p'-DDE** | **Fipronil** |
| | **Fipronil sulfone** |

for 25min, ramp at 25°C to 235°C, and hold for 15min. The carrier gas is UHP helium at 27cm/sec flow velocity with the inlet pressure at 13.24psi and inlet temperature at 250°C. The ECD temperature is 325°C with a constant make up gas flow of 65cc/min UHP nitrogen. The autoinjector is set at 1.0µL injection volume in the fast mode. Under these GC conditions the first 15 pesticides on the list in Table 1 (including the first two pyrethroids bifenthrin and ë-cyhalothrin) can be analyzed in a single run of 47.40min. Pesticide residues are confirmed with a HP 1MS capillary column (30m x .25mm i. d. x 0.25µm film thickness) under the same GC conditions and/or with the MSD. Online HP Pesticide and NIST search libraries are used when needed. GC methodology for analyzing the 6 pyrethroids in Table 1 (last 6 compounds) as a group in a single run has been reported elsewhere (Smith et al., 2001).

Nutrient and TOC analysis

Nutrient sample preparation and analyses for soluble $PO_4$-P, $NH_4$-N, and $NO_3$-N was as previously reported by Schreiber (1992) using Dionex automated anion chromatography (DX500) and Bran-Lubbe (TRAACS 800) automated flow-through colorimetry. Total soluble organic carbon (TOC) analyses were performed with a Rosemount Analytical Dohrmann DC-190 carbon analyzer with automatic liquid sampler.

Sediment

An automated laser scattering particle size distribution analyzer (Horiba LA910) is used for particle size determination. Sediment concentration in runoff is determined by the total suspended solids method (APHA, 1992).

## RESULTS AND DISCUSSION

Table 2 shows the pesticide analytical results for runoff samples collected thus far from the six pipe sites. As expected, there are no apparent differences in pesticide concentrations within treatment for both types of pipe sites. This is primarily the result of the fact that the VBs are newly-established and not providing any significant filtering/processing of runoff. The herbicides (e.g. trifluralin, atrazine, alachlor, metolachlor, cyanazine, pendimethalin) generally have relatively high water solubilities and low organic carbon coefficients and are probably transported in the soluble phase of runoff. The VBs, if well-established, would be expected to provide numerous sorption sites (plant surfaces) for retention of these types of compounds. Conversely, the insecticides [e.g. methyl parathion, fipronil, dieldrin, DDT (and metabolites), bifenthrin (and the other pyrethroids)] generally have relatively low water solubilities and high organic carbon coefficients and are likely transported attached to sediment. Since the VBs are not well-established, they provide very little sediment trapping ability.

Table 2. Pesticides in runoff from pipe sites.

| Sample # | VOLUME (mL) | Date | Trifluralin | Atrazine | Methyl parathion | Alachlor |
|---|---|---|---|---|---|---|
| A4 | 4000 | 4/11/2001 | 0.002 | 0.000 | 0.106 | 0.000 |
| A4 | 4000 | 4/17/2001 | 0.004 | 0.000 | 0.044 | 0.000 |
| A4 | 950 | 4/27/2001 | 0.008 | 0.000 | 0.246 | 0.000 |
| A4 | 780 | 5/11/2001 | 0.012 | 0.000 | 0.250 | 0.000 |
| A4 | 2110 | 6/19/2001 | 0.005 | 0.000 | 0.082 | 0.000 |
| A4 | 4000 | 6/28/2001 | 0.004 | 0.000 | 0.123 | 0.000 |
| A4 | 4000 | 8/16/2001 | 0.000 | 0.000 | 0.000 | 0.000 |
| A4 | 4000 | 9/14/2001 | 0.000 | 1.231 | 0.000 | 0.000 |
| A5 | 4000 | 4/11/2001 | 0.000 | 0.000 | 0.111 | 0.000 |
| A5 | 4000 | 4/17/2001 | 0.000 | 0.000 | 0.075 | 0.000 |
| A5 | 4000 | 4/27/2001 | 0.017 | 0.000 | 0.089 | 0.000 |
| A5 | 950 | 5/11/2001 | 0.021 | 0.000 | 0.190 | 0.000 |
| A5 | 1310 | 6/19/2001 | 0.022 | 0.000 | 0.055 | 0.000 |
| A5 | 4000 | 6/28/2001 | 0.000 | 0.000 | 0.035 | 0.000 |
| A5 | 4000 | 8/16/2001 | 0.000 | 0.017 | 0.027 | 0.000 |
| A5 | 4000 | 9/14/2001 | 0.000 | 1.289 | 0.044 | 0.007 |
| A6 | 4000 | 4/11/2001 | 0.004 | 0.000 | 0.063 | 0.000 |
| A6 | 4000 | 4/17/2001 | 0.007 | 0.000 | 0.049 | 0.000 |
| A6 | 4000 | 4/27/2001 | 0.009 | 0.000 | 0.056 | 0.000 |
| A6 | 2410 | 5/11/2001 | 0.005 | 0.000 | 0.081 | 0.000 |
| A6 | 4000 | 6/19/2001 | 0.003 | 0.000 | 0.042 | 0.000 |
| A6 | 370 | 6/28/2001 | 0.015 | 0.000 | 0.527 | 0.000 |
| A6 | 4000 | 8/16/2001 | 0.000 | 0.000 | 0.094 | 0.000 |
| A6 | 1080 | 9/14/2001 | 0.000 | 1.119 | 0.000 | 0.000 |
| B8 | 1310 | 5/11/2001 | 0.011 | 0.000 | 0.162 | 0.000 |
| B8 | 1100 | 6/19/2001 | 0.012 | 0.000 | 0.168 | 0.000 |
| B8 | 4000 | 6/28/2001 | 0.007 | 0.000 | 0.019 | 0.000 |
| B8 | 4000 | 8/16/2001 | 0.000 | 0.000 | 0.020 | 0.000 |
| B8 | 4000 | 9/14/2001 | 0.000 | 0.000 | 0.023 | 0.000 |
| N1 | 4000 | 5/11/2001 | 0.005 | 0.000 | 0.057 | 0.000 |
| N1 | 2140 | 6/19/2001 | 0.004 | 0.000 | 0.087 | 0.000 |
| N1 | 2000 | 6/28/2001 | 0.010 | 0.000 | 0.090 | 0.000 |
| N1 | 4000 | 8/16/2001 | 0.000 | 0.000 | 0.023 | 0.000 |
| N1 | 4000 | 9/14/2001 | 0.001 | 1.419 | 0.092 | 0.000 |
| N2 | 2100 | 5/11/2001 | 0.008 | 0.000 | 0.143 | 0.000 |
| N2 | 1270 | 6/19/2001 | 0.019 | 0.000 | 0.078 | 0.000 |
| N2 | 3450 | 6/28/2001 | 0.000 | 0.000 | 0.000 | 0.000 |
| N2 | 4000 | 8/16/2001 | 0.000 | 0.000 | 0.000 | 0.000 |
| N2 | 220 | 9/14/2001 | 0.000 | 1.523 | 0.000 | 0.000 |

Pesticide Concentration---ppb

| Metolachlor | Chlorpyrifos | Cyanazine | Pendimethalin | Fipronil | Dieldrin | pp'-DDE | Fipronil sulfone | Chlorfenapyr |
|---|---|---|---|---|---|---|---|---|
| 0.000 | 0.009 | 0.000 | 0.000 | 0.000 | 0.005 | 0.008 | 0.000 | 0.000 |
| 0.141 | 0.016 | 0.000 | 0.000 | 0.000 | 0.008 | 0.011 | 0.000 | 0.000 |
| 0.169 | 0.024 | 0.000 | 0.000 | 0.000 | 0.018 | 0.030 | 0.000 | 0.000 |
| 0.270 | 0.032 | 0.000 | 0.000 | 0.000 | 0.045 | 0.030 | 0.000 | 0.000 |
| 0.173 | 0.033 | 0.000 | 0.000 | 0.000 | 0.009 | 0.012 | 0.000 | 0.000 |
| 0.123 | 0.041 | 0.000 | 0.000 | 0.000 | 0.000 | 0.042 | 0.000 | 0.000 |
| 0.000 | 0.000 | 0.012 | 0.000 | 0.000 | 0.000 | 0.009 | 0.000 | 0.000 |
| 0.000 | 0.000 | 0.054 | 0.000 | 0.000 | 0.000 | 0.013 | 0.000 | 0.000 |
| 0.145 | 0.041 | 0.000 | 0.000 | 0.000 | 0.003 | 0.012 | 0.000 | 0.000 |
| 0.176 | 0.035 | 0.000 | 0.000 | 0.000 | 0.006 | 0.031 | 0.000 | 0.000 |
| 0.455 | 0.054 | 0.000 | 0.000 | 0.000 | 0.008 | 0.005 | 0.000 | 0.000 |
| 0.606 | 0.074 | 0.000 | 0.000 | 0.000 | 0.026 | 0.034 | 0.000 | 0.000 |
| 0.270 | 0.028 | 0.000 | 0.000 | 0.000 | 0.022 | 0.017 | 0.000 | 0.000 |
| 0.121 | 0.012 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.008 | 0.020 | 0.000 | 0.000 |
| 0.102 | 0.010 | 0.050 | 0.004 | 0.000 | 0.002 | 0.004 | 0.000 | 0.000 |
| 0.062 | 0.009 | 0.000 | 0.000 | 0.000 | 0.009 | 0.030 | 0.000 | 0.000 |
| 0.178 | 0.027 | 0.000 | 0.000 | 0.000 | 0.015 | 0.027 | 0.000 | 0.000 |
| 0.208 | 0.030 | 0.000 | 0.000 | 0.000 | 0.012 | 0.025 | 0.000 | 0.000 |
| 0.120 | 0.020 | 0.000 | 0.000 | 0.000 | 0.009 | 0.017 | 0.000 | 0.000 |
| 0.026 | 0.007 | 0.000 | 0.000 | 0.000 | 0.005 | 0.009 | 0.000 | 0.000 |
| 0.543 | 0.092 | 0.000 | 0.000 | 0.000 | 0.067 | 0.055 | 0.000 | 0.000 |
| 0.188 | 0.059 | 0.180 | 0.000 | 0.000 | 0.013 | 0.023 | 0.000 | 0.000 |
| 0.000 | 0.000 | 0.078 | 0.000 | 0.000 | 0.000 | 0.032 | 0.000 | 0.000 |
| 0.159 | 0.028 | 0.000 | 0.000 | 0.000 | 0.027 | 0.036 | 0.000 | 0.000 |
| 0.238 | 0.050 | 0.000 | 0.000 | 0.000 | 0.063 | 0.047 | 0.000 | 0.000 |
| 0.097 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| 0.000 | 0.000 | 5.321 | 0.005 | 0.018 | 0.010 | 0.004 | 0.000 | 0.000 |
| 0.000 | 0.002 | 0.079 | 0.000 | 0.009 | 0.010 | 0.005 | 0.000 | 0.000 |
| 0.089 | 0.010 | 0.000 | 0.000 | 0.000 | 0.004 | 0.007 | 0.000 | 0.000 |
| 0.115 | 0.020 | 0.000 | 0.000 | 0.000 | 0.008 | 0.013 | 0.000 | 0.000 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.009 | 0.020 | 0.000 | 0.000 |
| 0.000 | 0.000 | 7.118 | 0.000 | 0.000 | 0.017 | 0.008 | 0.000 | 0.128 |
| 0.057 | 0.007 | 0.184 | 0.002 | 0.000 | 0.004 | 0.024 | 0.000 | 0.012 |
| 0.141 | 0.013 | 0.000 | 0.000 | 0.000 | 0.012 | 0.015 | 0.000 | 0.000 |
| 0.095 | 0.007 | 0.000 | 0.000 | 0.000 | 0.000 | 0.023 | 0.000 | 0.000 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.000 | 0.000 | 6.890 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.034 | 0.039 | 0.000 | 0.000 |

| pp' -DDD | pp' -DDT | Bifenthrin | λ-Cyhalothrin | Cyfluthrin | Zeta-cypermenthrin | Esfenvalerate | Deltamethrin |
|---|---|---|---|---|---|---|---|
| 0.014 | 0.431 | 0.005 | 0.003 | 0.008 | 0.000 | 0.000 | 0.000 |
| 0.018 | 0.702 | 0.015 | 0.002 | 0.003 | 0.000 | 0.000 | 0.000 |
| 0.036 | 0.911 | 0.032 | 0.009 | 0.005 | 0.000 | 0.001 | 0.000 |
| 0.088 | 0.975 | 0.033 | 0.028 | 0.000 | 0.003 | 0.000 | 0.000 |
| 0.019 | 0.583 | 0.017 | 0.007 | 0.065 | 0.000 | 0.000 | 0.008 |
| 0.022 | 1.011 | 0.009 | 0.011 | 0.012 | 0.000 | 0.000 | 0.000 |
| 0.031 | 0.999 | 0.000 | 0.003 | 0.084 | 0.000 | 0.000 | 0.000 |
| 0.043 | 0.876 | 0.000 | 0.005 | 0.011 | 0.000 | 0.000 | 0.000 |
| 0.033 | 1.009 | 0.033 | 0.032 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.035 | 0.993 | 0.045 | 0.041 | 0.004 | 0.000 | 0.005 | 0.000 |
| 0.000 | 0.889 | 0.032 | 0.031 | 0.007 | 0.000 | 0.000 | 0.000 |
| 0.064 | 1.442 | 0.097 | 0.019 | 0.001 | 0.004 | 0.000 | 0.000 |
| 0.050 | 0.943 | 0.006 | 0.011 | 0.043 | 0.000 | 0.000 | 0.000 |
| 0.024 | 0.774 | 0.007 | 0.023 | 0.015 | 0.000 | 0.000 | 0.006 |
| 0.046 | 0.144 | 0.050 | 0.013 | 0.071 | 0.000 | 0.000 | 0.000 |
| 0.008 | 0.171 | 0.017 | 0.019 | 0.021 | 0.000 | 0.000 | 0.000 |
| 0.047 | 0.719 | 0.008 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.033 | 0.637 | 0.070 | 0.000 | 0.007 | 0.000 | 0.000 | 0.000 |
| 0.035 | 1.578 | 0.009 | 0.006 | 0.008 | 0.002 | 0.006 | 0.009 |
| 0.022 | 0.634 | 0.052 | 0.007 | 0.004 | 0.000 | 0.000 | 0.000 |
| 0.009 | 0.169 | 0.013 | 0.003 | 0.079 | 0.000 | 0.000 | 0.000 |
| 0.110 | 1.413 | 0.044 | 0.025 | 0.015 | 0.000 | 0.000 | 0.006 |
| 0.076 | 1.375 | 0.096 | 0.053 | 0.091 | 0.000 | 0.003 | 0.000 |
| 0.098 | 1.112 | 0.000 | 0.015 | 0.013 | 0.000 | 0.000 | 0.000 |
| 0.044 | 0.541 | 0.079 | 0.009 | 0.001 | 0.001 | 0.000 | 0.000 |
| 0.117 | 0.795 | 0.059 | 0.011 | 0.004 | 0.000 | 0.000 | 0.000 |
| 0.014 | 0.678 | 0.054 | 0.012 | 0.004 | 0.000 | 0.000 | 0.004 |
| 0.018 | 0.107 | 0.006 | 0.010 | 0.000 | 0.003 | 0.007 | 0.000 |
| 0.020 | 0.100 | 0.009 | 1.341 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.024 | 0.132 | 0.005 | 0.002 | 0.004 | 0.000 | 0.000 | 0.000 |
| 0.053 | 0.209 | 0.005 | 0.004 | 0.002 | 0.000 | 0.000 | 0.004 |
| 0.055 | 0.489 | 0.008 | 0.008 | 0.000 | 0.005 | 0.005 | 0.000 |
| 0.031 | 0.123 | 0.023 | 0.613 | 0.005 | 0.000 | 0.000 | 0.001 |
| 0.033 | 0.143 | 0.027 | 0.014 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.111 | 0.757 | 0.007 | 0.012 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.087 | 0.897 | 0.003 | 0.008 | 0.007 | 0.007 | 0.009 | 0.000 |
| 0.000 | 0.564 | 0.005 | 0.005 | 0.009 | 0.000 | 0.000 | 0.000 |
| 0.214 | 0.789 | 0.000 | 0.132 | 0.000 | 0.000 | 0.000 | 0.006 |
| 0.313 | 0.842 | 0.000 | 0.204 | 0.001 | 0.000 | 0.000 | 0.000 |

Table 3 shows the results of analysis of pipe runoff for sediment concentration, nutrient concentrations, and total organic carbon content. As with the pesticide concentrations, there are no apparent differences within treatment for both types of pipe sites. This is also likely because the VBs are newly-established and not providing any significant filtering/processing of runoff. Overall, sediment concentrations are lower in runoff from the SI pipes than in runoff from the SBR pipes. The SBR pipes drain fields with heavier, finer-textured soils; whereas, the SI pipes drain fields with lighter, coarser-textured soils.

Table 3. Sediment concentration, nutrients, and total organic carbon in runoff from pipe sites.

| Sample # | VOLUME (mL) | Date | SEDIMENT CONC. (mg/L) | NO3-N (mg/L) | NH4-N (mg/L) | PO4-P (mg/L) | TOC (mg/L) |
|---|---|---|---|---|---|---|---|
| A4 | 4000 | 4/11/2001 | 353 | 2.03 | 0.12 | 0.09 | 75 |
| A4 | 4000 | 4/17/2001 | 555 | 1.01 | 0.32 | 0.12 | 81 |
| A4 | 950 | 4/27/2001 | 765 | 0.98 | 0.15 | 0.04 | 76 |
| A4 | 780 | 5/11/2001 | 312 | 0.92 | 0.34 | 0.14 | 57 |
| A4 | 2110 | 6/19/2001 | 435 | 0.45 | 0.32 | 0.11 | 88 |
| A4 | 4000 | 6/28/2001 | 211 | 0.33 | 0.19 | 0.08 | 90 |
| A4 | 4000 | 8/16/2001 | 321 | 0.27 | 0.43 | 0.06 | 49 |
| A4 | 4000 | 9/14/2001 | 109 | 0.12 | 0.26 | 0.03 | 78 |
| A5 | 4000 | 4/11/2001 | 344 | 2.37 | 0.11 | 0.06 | 88 |
| A5 | 4000 | 4/17/2001 | 457 | 2.11 | 0.21 | 0.10 | 90 |
| A5 | 4000 | 4/27/2001 | 675 | 1.92 | 0.09 | 0.09 | 65 |
| A5 | 950 | 5/11/2001 | 421 | 0.92 | 0.31 | 0.11 | 78 |
| A5 | 1310 | 6/19/2001 | 323 | 0.56 | 0.22 | 0.05 | 98 |
| A5 | 4000 | 6/28/2001 | 321 | 0.43 | 0.33 | 0.03 | 49 |
| A5 | 4000 | 8/16/2001 | 190 | 0.90 | 0.21 | 0.09 | 88 |
| A5 | 4000 | 9/14/2001 | 212 | 0.76 | 0.42 | 0.05 | 99 |
| A6 | 4000 | 4/11/2001 | 834 | 0.47 | 0.09 | 0.06 | 101 |
| A6 | 4000 | 4/17/2001 | 945 | 0.22 | 0.26 | 0.10 | 98 |
| A6 | 4000 | 4/27/2001 | 1657 | 0.13 | 0.33 | 0.03 | 87 |
| A6 | 2410 | 5/11/2001 | 654 | 0.43 | 0.16 | 0.07 | 67 |
| A6 | 4000 | 6/19/2001 | 432 | 0.98 | 0.18 | 0.09 | 59 |
| A6 | 370 | 6/28/2001 | 333 | 0.76 | 0.19 | 0.04 | 88 |
| A6 | 4000 | 8/16/2001 | 318 | 1.01 | 0.25 | 0.06 | 95 |
| A6 | 1080 | 9/14/2001 | 217 | 0.99 | 0.10 | 0.03 | 88 |
| B8 | 1310 | 5/11/2001 | 121 | 1.92 | 0.33 | 0.11 | 77 |
| B8 | 1100 | 6/19/2001 | 143 | 2.09 | 0.24 | 0.07 | 65 |
| B8 | 4000 | 6/28/2001 | 89 | 1.87 | 0.34 | 0.07 | 87 |
| B8 | 4000 | 8/16/2001 | 44 | 0.45 | 0.31 | 0.09 | 59 |
| B8 | 4000 | 9/14/2001 | 56 | 0.76 | 0.34 | 0.04 | 80 |
| N1 | 4000 | 5/11/2001 | 137 | 2.93 | 0.19 | 0.05 | 87 |
| N1 | 2140 | 6/19/2001 | 211 | 2.06 | 0.44 | 0.08 | 69 |
| N1 | 2000 | 6/28/2001 | 98 | 1.55 | 0.15 | 0.06 | 98 |
| N1 | 4000 | 8/16/2001 | 75 | 0.76 | 0.12 | 0.10 | 77 |
| N1 | 4000 | 9/14/2001 | 78 | 0.43 | 0.32 | 0.07 | 89 |
| N2 | 2100 | 5/11/2001 | 129 | 2.22 | 0.45 | 0.08 | 98 |
| N2 | 1270 | 6/19/2001 | 234 | 1.77 | 0.34 | 0.04 | 87 |
| N2 | 3450 | 6/28/2001 | 101 | 1.45 | 0.17 | 0.13 | 86 |
| N2 | 4000 | 8/16/2001 | 78 | 0.77 | 0.25 | 0.09 | 89 |
| N2 | 220 | 9/14/2001 | 34 | 0.63 | 0.43 | 0.09 | 65 |

## CONCLUSION

We feel that once the VBs become well-established, we will observe and be able to quantify significant improvements in water quality from those modified field drainage pipes that have VBs as compared with those that do not. Also, we expect to see improvements in water quality from SBR pipes versus SI pipes. In North Carolina, for example, controlled drainage replaces natural riparian buffers on about 300,000 acres of cropland and is used as an approved BMP (Gilliam et al., 1994; Gilliam, 1998). Nitrogen losses can be reduced by 50 percent, and the practice is accepted by farmers since in improves corn and soybean yields by about 10 percent.

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*Mention of a pesticide in this paper does not constitute a recommendation for use by the U. S. Department of Agriculture nor does it imply registration under FIFRA as amended. Names of commercial products are included for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture. All programs and services of the U. S. Department of Agriculture are offered on a nondiscriminatory basis without regard to race, color, national origin, religion, sex, marital status, or handicap*

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## APPENDIX

*Chemical names of pesticides mentioned in this paper*

alachlor (2-chloro-2′,6′-diethyl-*N*-methoxymethylacetanilide) aldrin [(1*R*,4*S*,4a*S*,5*S*,8*R*,8a*R*)-1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-dimethanonaphthalene]

atrazine (2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine) Aatrex

bifenthrin [2-methylbiphenyl-3-ylmethyl (*Z*)-(1*RS*,3*RS*)-3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2-dimethylcyclopropanecarboxylate] Capture

chlorfenapyr [4-bromo-2-(4-chlorophenyl)-1-(ethoxymethyl)-5-(trifluoromethyl)-1H-pyrrole-3-carbonitrile] Pirate

chlorpyrifos (*O*,*O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate) Lorsban

cyanazine [2-(4-chloro-6-ethylamino-1,3,5-triazin-2-ylamino)-2-methylpropionitrile]

cyfluthrin [*RS*-*a*-cyano-4-fluoro-3-phenoxybenzyl(1*RS*,3*RS*)-*cis,trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate] Baythroid

ë-cyhalothrin {[1á(*S**),3*á*(*Z*)]-cyano(3-phenoxyphenyl)methyl 3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethylcyclopropanecarboxylate]} Karate

DDD [1,1-dichloro-2,2-bis (*p*-chlorophenyl) ethane]

DDE [1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene]

DDT [1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane]

deltamethrin [(*S*)-*a*-cyano-3-phenoxybenzyl (1*R*,3*R*)-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropanecarboxylate]

dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a,octahydro-1,4,5,8-dimethanonaphthalene)

endosulfan (6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiopin-3-oxide)

endrin (1,2,3,4,10,10-hexachloro-1*R*,4*S*,4a*S*,5*S*,6,7*R*,8*R*,8a*R*-octahydro-6,7-epoxy-1,4:5,8-dimethanonaphthalene)

esfenvalerate {[*S*-(*R**,*R**)]-cyano(3-phenoxyphenyl)methyl 4-chloro-á-(1-methylethyl)benzeneacetate} Asana XL

fipronil [(*RS*)-5-amino-1-(2,6-dichloro-*á*,*á*,*á*-trifluoro-*p*-tolyl)-4-trifluoromethylsulfinylpyrazole-3-carbonitrile] Regent

fluometuron [*N*,*N*-dimethyl-*N'*-(3-(trifluoromethyl)phenyl)-urea] Cotoran

heptachlor (1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene)

methoxychlor (2,2-bis(p-methoxyphenyl)-1,1,1-trichloroethane)

methyl parathion (*O*,*O*-dimethyl-*O*-*p*-nitrophenyl phosphorothioate)

metolachlor [2-chloro-6'-ethyl-*N*-(2-methoxy-1-methylethyl)acet-*o*-toluidide] Dual

norflurazon [4-chloro-5-(methylamino)-2-(*á*,*á*,*á* -trifluoro-*m*-tolyl)-3(2*H*)-pyridazinone] Zorial

pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] Prowl

trifluralin (*a*,*a*,*a*-trifluro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) Treflan

zeta-cypermethrin [(*S*)-*á*-cyano-3-phenoxybenzyl (1*RS*,3*RS*;1*RS*,3*SR*)-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate] Fury